

A close-up photograph of a giant panda sitting in a bamboo grove. The panda is holding a bamboo stalk in its mouth and is in the process of eating it. Its black and white fur is clearly visible, and its black eye patches are prominent. The background is filled with green bamboo leaves and branches, creating a naturalistic setting.

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Features

The Giant Panda 5



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Mary W. Matthews,
Editor
Mary C. Massey,
Consulting Editor
Rebecca McClimans,
Design and Production

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The Lady and the Panda 8 *By Margery Facklam*

Red Pandas at the National Zoo 11 *by Ronn Brackin*



Will the Real Panda . . ? 14

In Search of the Fire Cat 16 *by Miles Roberts*



Departments

ZooNews 21



Contributors 25

BookNews 26

FRONT COVER: The giant panda Hsing-Hsing is one of the best-known of Washington celebrities. BACK COVER: Although its weight as an adult is only about three percent that of the giant panda, the red panda is its nearest relative. Both photos courtesy NZP Office of Graphics and Exhibits.



The Giant Panda

Surprisingly little is known about the life of the giant panda in the wild. No detailed field studies have ever been done; so the "bei-shung" ("white bear," or panda), known to westerners only since 1869, is still as elusive as it is fascinating.

Experts cannot even agree on whether the giant panda should be classified as a bear or a raccoon. Anatomically, the giant panda (known to taxonomists as *Ailuropoda melanoleuca*, or "black-and-white cat-footed animal") seems like a highly specialized bear. But giant pandas are more like raccoons with respect to their skulls, teeth, stomachs, and chromosomal structure. Also, bears roar, whereas pandas bleat or cough. Recent chromosome studies indicate that scientists were correct in assigning giant pandas and their cousins the red pandas a taxonomic family all their own.

The giant panda inhabits a small and remote region of western China near the Tibetan border. Most giant pandas live in China's Szechuan province. Within its range, the giant panda is usually found in the coniferous forests and dense bamboo thickets that cover the mountain-



Giant pandas are found in the wild only in China's Szechuan and Kansu provinces, although once they roamed the Himalayas. The Chinese have made gifts of giant pandas to London, Paris, Tokyo, North Korea, Madrid, Mexico City, and Washington, D.C.

sides between 5,000 and 10,000 feet above sea level.

Although the provinces of Szechuan and Kansu are at the same latitude as Florida, their high altitude makes them inhospitable to all but the most hardy. Snow covers the ground from October to May. In other seasons rain is almost continuous. Summer temperatures rarely exceed 50° F.

Several other unique mammals share this bamboo belt. One of these is the golden-brown takin, which looks something like the musk ox.

The takin is so closely associated with the bamboo forests that early hunters took its presence as a sure sign there were giant pandas nearby. The red panda is also found in giant panda country, although its range includes both lower and higher altitudes. Other unusual residents are the golden-haired monkey, leopards, lynxes, and the Himalayan black bear.

Adult pandas are solitary. Each one has its own home range, but the average size of this range is unknown. One observer believes it's only one

Left, the National Zoo's 10- to 11-year-old Ling-Ling munches on her favorite food.

square mile. Others think that since pandas are so large, the one square mile might represent the most frequently used portion of a larger range. Like bears, each panda defends its territory against other pandas. Pandas warn away intruders and attract each other by marking their territory with scent.

This form of territorial identification is called scent-marking. Giant pandas of both sexes have scent glands under their tails. Hsing-Hsing, the National Zoo's male giant panda, uses both his urine and scent glands to mark walls, logs, and other objects in his enclosure every morning. Sometimes he does a "handstand" while marking: Forefeet on the ground, he walks his hind feet up the wall until he can press his posterior scent glands against it.

Females are believed to scent-mark less frequently than males; Ling-Ling, the Zoo's female giant panda, scent-marks less often than Hsing-Hsing does. The exception to this rule comes during breeding season, when both sexes increase their scent-marking. In the wild this increased activity must help the adults of this solitary species find one another.

Each giant panda travels along well-established paths through the bamboo thickets, stopping every hundred yards or so to feed. Observers have noted that the giant panda is most active in feeding around dawn and dusk, sleeping at midday and during the middle of the night. This pattern of activity is called crepuscular. (Diurnal means active by day; nocturnal, active at night.) Scientists at the National Zoo have

noted that Hsing-Hsing and Ling-Ling are most active in the early morning and from dusk to after midnight. They sleep during the middle of the day and the latter part of the night.

Whatever the pattern, giant pandas, like bears, often make sleeping nests. The nest is formed of bamboo stalks twisted together—perhaps so that the panda will not have to go far for a "midnight snack"! Pandas are also said to hole up in hollow trees or under rock ledges.

Giant panda trails, nests, feeding sites, and droppings have been found by explorers much more often than pandas themselves. The feeding sites are said to be particularly easy to find, consisting of one or two square yards that have been cleared of bamboo by the panda. According to one account, the panda bites off 15 to 20 bamboo stalks at each feeding site and piles them up. These stems may be from five to 18 feet tall.

It has been said that the panda eats the middle part of the stalk and rejects both the leaves and the tough bottom. In the wild, this may be so; but many young captive specimens, including Hsing-Hsing and Ling-Ling, seem to prefer the leaves.

While feeding, the giant panda lies on its back or side, or sits with its hind legs outstretched in the characteristically slouching seated posture so familiar to Zoo visitors. It raises to its mouth one of the stalks it has broken off and, with a twisting movement of the forepaw and a sideways jerk of the head, strips off the bamboo's tough outer layer. Then it bites off a section of the peeled stalk, chews it methodically, and swallows.

One of the giant panda's most interesting features is its unique pseudthumb, an elongation of its wristbone that enables it to pick up and hold objects with surprising precision. The pseudthumb appears as a furrow between the wristbone pad and the palm pad when the panda flexes its forepaw—a little bit like the furrow that would appear if a human were to flex his hand inside a thumbless mitten. The pseudthumb is so dexterous that giant pandas have been observed picking up straws and small pieces of food. Hsing-Hsing and Ling-Ling can even pick up their metal feed trays by the edge.

Even the youngest and tenderest of bamboo shoots are not easy to chew and digest; and, of course, in winter, mature stalks are all that is available. So it is not surprising that the giant panda has been called a strikingly well-developed grinding machine, with its huge molars and cheek teeth and powerful chewing muscles.

The giant panda's digestive system, however, is surprisingly inefficient. Though its esophagus and stomach are thick-walled and very muscular (the better to remain untorn by splinters of bamboo), the panda's small intestine, usually fairly long in herbivorous (plant-eating) mammals, is unusually short. Evidently bamboo is so difficult to digest that, after it has been ground up as much as possible in the mouth and stomach, it must be passed quickly through to the large intestines where it can be acted on by internal bacteria and protozoa.

Even so, the giant panda is unable to absorb anywhere near all of bam-

boo's potential nourishment; so its droppings are characterized by large amounts of undigested matter.

To compensate for bamboo's relatively low nutritional value and relatively high indigestibility, plus the inefficiency of the giant panda's digestive system, a panda may in the wild spend up to 12 hours a day feeding. If that is so, it would seem that pandas do little else; but then, they have little else to do. Pandas have few, if any, enemies aside from human beings. Perhaps significantly, captive pandas seem to lose most of their interest in food during mating season.

How much of the giant panda's diet in the wild is made up of foods other than bamboo is still unknown. Analysis of the droppings of wild pandas has shown occasional traces of small mammals and birds. It is certainly untrue—although it has often been said—that the panda's diet is exclusively bamboo. Crocuses, irises, and grass have also been reported as occasional food items, and sometimes a panda will invade a field of corn. Bamboo is unavailable in Moscow, but the Moscow Zoo's long-lived male panda, An-An, successfully adjusted to a diet of birch twigs. In fact, the giant panda—like many bears—has a sweet tooth. Early travelers reported that pandas frequently raided farmers' beehives. When Zoo keepers want to entice Hsing-Hsing or Ling-Ling, they use honey as bait.

Giant pandas are good if slow climbers. They often climb to the tops of tall trees to rest during the day or, according to natives, "sun themselves." They hoist themselves



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To eat, pandas break off bamboo into small stalks, strip off the tough outer layers with their powerful molars. Pandas can grasp and lift objects with their forepaws, which have a unique sixth digit like a thumb.

Hsing-Hsing (left) scent-marks his enclosure.

up by hugging the trunk, as bears do. They usually climb down tail first, but they may walk down a more horizontal branch head first.

Although contradicted by some western observers, Chinese experts say that pandas love water. Chen Ho-yi, assistant at the Chinese Academy of Sciences' Institute of Zoology, re-

ported that pandas "sometimes continue drinking until they are so full that they can only waddle. One giant panda actually lost consciousness through over-drinking; it was found by members of a production team who stood guard till it came to and was able to go safely on its way."

Continued on page 25

The Lady & The Panda

BY MARGERY FACKLAM

Today when being transported, exotic animals are tranquilized and shipped as carefully as cargos of crystal. They travel in air-conditioned jets, and are attended by veterinarians and zoologists. When Ling-Ling and Hsing-Hsing were shipped to the National Zoo, the operation followed a schedule as detailed as any military operation. But in 1936, when the first giant panda was brought to the western world, it was a one-woman operation, and it was successful more from luck and determination than from skill or knowledge.

In the 1930s animal collectors shared top billing with movie stars and matinee idols. Frank Buck's famous slogan, "Bring 'Em Back Alive," blinked from the theater marquees where he showed his films. Martin and Osa Johnson, who delivered the first gorillas to the San Diego Zoo, were surrounded by autograph seekers wherever they lectured.

Ruth Harkness, however, stepped into the animal collecting business a total innocent. She was a dress designer who "inherited" an expedition but who went on to capture the animal destined to make the top 10 on everyone's "favorite animal" list.

Until 1936 no one had seen a live giant panda outside its native habitat, and few people *in* Asia had seen the elusive, bear-like beast that roamed

the snow-covered slopes of the high Himalayas.

In 1928 Teddy Roosevelt's sons Kermit and Theodore Jr. shot a giant panda in Szechuan province near the China-Tibet border, and gave its skin to the Field Museum in Chicago. That exhibit triggered a small flurry of trophy-hunting expeditions—but fortunately for pandas, that kind of trip was too expensive for all but a few "great white" hunters.

In spite of such publicity, Ruth Harkness had never heard of a panda. When her husband told her he was off to China to capture a giant panda for the Bronx Zoo, Ruth said, "Giant panther, don't you mean?"

William Harkness was an explorer and animal collector just back from capturing Komodo dragons for the Bronx Zoo when he organized his panda expedition. Ruth asked to go along, but she was told that it "wasn't that a woman couldn't make herself useful, but governments make such a fuss if anything happens to a woman."

So Ruth stayed in New York City. Months went by with little word except for the message that the expedition could get no permit to go into the interior of China. It was then 1934. Newspapers were reporting "great unrest in Asia," and Ruth read with fear the accounts of Japan in-

vading Manchuria. Finally, a cable arrived: William Harkness had died in Shanghai of an unnamed disease.

"I had inherited an expedition," Ruth wrote in her journal.

Knowing nothing about either pandas or expeditions, Ruth decided to go to China. Against the advice of friends who knew that her most athletic moment was running for a cab, or that her knowledge of animals was limited to her experiences with one kitten, she went.

She had a lot of time to think about that decision on the long, slow voyage across the Atlantic and around India to Shanghai. There, sweltering in the heat, she spent months settling accounts and sorting equipment left in a warehouse by her husband's partners. The English colony entertained her with hair-raising tales of what the Red Army did to captured foreigners and how she would die of dysentery if she wasn't shot by bandits.

In spite of it all, Ruth fell in love with China. "There was a curious feeling in me that this was not an alien land, a strange and foreign country, but in some inexplicable way. . . home," she wrote.

Ruth found a guide, Quentin Young, the brother of the man who had taken the Roosevelts into panda country. Together they assembled



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equipment from her late husband's expedition, which included enough guns and ammunition to start a small army. Neither of them had any idea of what to take to trap a 300- or 400-pound animal. Finally, they added five big traps, bales of wire, and coils of rope to the inventory.

At that point Ruth reported that she did not really expect to find an animal; she did hope to stay until she saw one, however. One night, going over lists, it occurred to her that they might have trouble taking a huge and reluctant animal down a mountain, so "why not get a baby one."

"I got out of bed and made a shopping note on my memo pad," she wrote. "Nursing bottle, nipples, dried milk."

In September 1936, just two years after her husband had started the venture, Ruth made the first leg of the 1,500-mile trip on a slow steamer up the Yangtze River. Overland they used rickety trucks and wheelbarrows, but mostly they walked. The porters offered to carry Ruth, but she refused. It became a matter of pride, although, she wrote, "most often I was straggling in the rear."

In the mountains of Szechuan, they had to climb higher and slipperier slopes and scramble over swaying rope bridges and pathways. With the first base camp at last set up, Ruth looked forward to weeks, even months, of resting, exploring, writing. But only two days after the last tent was in place, Quentin, who had gone

When Su Lin was colicky in Shanghai, Ruth called in a pediatrician—who said, "A pandor? Sounds disagreeable." But he came to her hotel and examined the infant giant panda.

on to set up two more sites from which to lay traps, came racing into camp shouting "Bei-shung!" He had seen signs of the giant panda, claw marks on bamboo and fresh dung.

At dawn the next morning, November 9, Ruth, Quentin, an old native named Tsang, and two porters set out to check traps. It was a steady climb in a cold, drizzling rain.

"In places the bamboo had fallen and made slimy traps into which I sank to my waist," Ruth said. "By that time I was proceeding mostly on hands and knees."

Suddenly the silence was exploded by a shot. Ruth was furious. She had given orders for no shooting in the trapping area. "What is it?" she called.

"Bei-shung," Quentin's voice echoed from the slopes ahead.

Ruth listened, but heard only dripping water from leaves. She hurried through bamboo thickets. "I could see him dimly through the wet branches," she reported. "I stumbled blindly, brushing water from my face and eyes. Then I, too, stopped, frozen in my tracks. From the old dead tree came a baby's whimper."

Quentin was already reaching into the hollow of a large tree. He pulled out a fuzzy ball and handed it to Ruth. "I reached for the tiny thing, a squirming baby bei-shung, not a fantasy." The baby nuzzled her jacket. "It's hungry," Ruth said, and they raced back to camp, Ruth sliding most of the way on her seat. Quentin carried the infant panda inside his shirt.

After a few moments, the panda, named Su Lin ("a little bit of something very cute," in the dialect of that

Drawing by Margaret Brown



The FONZ Bookstore/Gallery and gift shops have the widest selection of one-of-a-kind giant panda items in the world.

province) nursed greedily. Its eyes were still closed.

Although they questioned all the porters and searched the area, there was no sign of the mother panda, nor any other panda. Ruth had the men gather bamboo to take back to the States so that the zoo that kept Su Lin could find a similar food.

To ensure the cub's health, the Chinese porters staged a sacrificial ceremony that night. They stabbed a rooster three times in the neck, burned paper money, poured wine on the ground, and set off firecrackers. Ruth added her part to the ceremony by firing her revolver three times in the air.

That Ruth and Su Lin arrived safely in America was a miracle. . . down the mountains, back to Shanghai, and eventually to America, Ruth was dogged by problems. In Shanghai, Su

Lin was colicky and too warm. Delayed by a 16-day shipping strike, Ruth's next battle was with customs officials, who noticed she had no permit. Knowing of her husband's failure to get one, and facing a similar series of delays from the Chinese, Ruth had gone ahead without one. After a night arguing, Ruth emerged from the customs offices with a \$20 permit for "one dog."

At long last in New York, Su Lin was examined by Bronx Zoo officials. Her hind legs looked weak; did she have rickets? What would they feed her? For unrecorded reasons, the Bronx Zoo turned down the panda, and Chicago's Brookfield Zoo eagerly accepted the first giant panda in captivity.

As the first female guests invited to the exclusive Explorer's Club, Ruth and Su Lin were welcomed by standing ovations. Newspapers called the public excitement over the two "panda-monium."

An experienced animal collector, Tangier Smith, accused Ruth of buying the panda, claiming that Su Lin was his and that he had been "keeping an eye on her" until she was old enough to be taken from her mother. Ruth denied it.

But had Quentin bought the animal and planted it for Ruth to "find"? Was Ruth naive? It makes no difference now; the glory is still hers. She had done the near-impossible, keeping a rare infant alive and well under adverse circumstances.

Ruth Harkness died at 41, alone in New York. Not much is known of her life outside her panda days. But she must have been as rare an individual as the panda. □

Red Pandas At the National Zoo

BY RONN BRACKIN

You are thousands of feet above sea level, in the foothills of the Himalayas. The mountain air is cool and moist, the forest thick with poplar, pine, and bamboo. Let your eye follow a tree limb upward. If you are very still and have an angel on your shoulder, you may see "Wah." "Wah" is the name given this elusive animal by some of the natives. In 1825, French naturalist Frederic Cuvier called it *Ailurus fulgens*: . . . Fire Cat.

Describing the red panda is a great deal more difficult than naming it. The inimitable Dr. Seuss would probably come pretty close if he took a little bit of cat, mixed it with a touch of bear, added a dash of fox and gave it the size and tail of a raccoon.

Little is known for certain about the red panda. Studies, including those by Keeper David S. Kessler and Curator Miles Roberts at the National Zoological Park, indicate that red pandas are shy, nocturnal, and for the most part vegetarian. In captivity, they mate in January and February and have their cubs (some zoologists prefer to call them kittens) about four months later. At birth, the cubs have a full coat of fluffy, buff-colored fur. They cannot see, and they are totally dependent on their

D.L. Golobitsh



In mountainous Nepal, the lichens and mosses that hang from the trees provide an ideal camouflage for the red panda, and may account for its unique coloration.

mothers. They open their eyes after a couple of weeks and leave the nest about three and a half months later. But they still need their mother's milk for a while before completely changing over to their new diet.

Red pandas in the wild are believed to rely mostly on bamboo supplemented with roots, soft bark, and buds. Bamboo is their main staple here at the National Zoo as well. But in captivity, their diet is supplemented with a sweet gruel and slices of fruit. Each red panda is fed twice a day and can put away an entire shoot of bamboo before the next sunrise, thus easily maintaining its cuddlesome-looking ten pound figure.

A red panda lives more than a decade in captivity, and it can reproduce throughout most of that lifetime. Presently there are seven adult red pandas here at the Zoo. Sixteen more, including nearly a dozen cubs, are at the 3,150-acre Conservation and Research Center outside Front Royal, Virginia, where researchers are looking for ways to make the red pandas happier and more comfortable away from their Asian homeland.

Rarely does a day go by at the Zoo without someone asking about the difference between the red panda and its big black and white cousin, the giant panda. As Miles Roberts likes to describe the scene, the keeper or curator "shuffles uncomfortably from foot to foot, stares off into the distance to avoid the questioning visitor's gaze, admits that nobody really knows for sure, and says—'We're working on it.' "

What is known is that both the red

and giant pandas eat bamboo. Both have semi-retractable claws. Both have similar wristbones in their forefeet, similar dental structures, and similar blood proteins. There are also resemblances in digestive systems and scent-marking behaviors. But red pandas have fur on the soles of their feet, whereas giant pandas have tough, fleshy pads like a bear's. The two species differ in size, coloration, and range. The giant panda can eat while lying on its side; the red panda usually stands on three feet to eat.

Being nocturnal animals, red pandas are mostly inactive during the day. But when they're not curled up on a tree branch in the winter or draped over one in the summer, their behavior can be observed by visitors. If you see a red panda squat on a rock or twig and do a little shimmy, he's probably scent-marking. (I say "he" because males are believed to scent-mark more often than females.)

In scent-marking, the red panda deposits a little urine and a secretion from his anal gland on the object to be marked and rubs it in with a series of circular movements. No one is sure why. The red pandas could be marking their territory as a warning to invaders, or they could simply be reinforcing their familiarity with their surroundings.

Another theory is that they are communicating information to one another. The male, for example, might be leaving an amorous odor-message for any females who pass that way. As far as we know, red pandas are solitary animals, getting together only to start a family and then moving on.

Are red pandas an endangered

species? No one really knows, because no one is sure how many there are or how many there should be. On a FONZ-supported field research project, Miles Roberts spent several months in Nepal looking for the answers—but he'll tell you that story. [Ed. note: See "Search for the Fire Cat" on page 00.]

Red pandas are not a widely-known species except among zoologists. Their fur reportedly holds little commercial value, and they are said to have few natural predators.

Red pandas are believed to be susceptible to only a few diseases. They are clean animals, washing themselves daily as cats do. But in captivity, they are prone to distemper and must be inoculated regularly.

Another strange phenomenon keepers must watch out for is something informally known as the "panda blahs." David Kessler says some red pandas pick up the "blahs" during the hot summer months. They become lethargic and stop eating. Kessler says one cure is to feed them lots of bamboo.

Red pandas communicate through a range of high- and low-frequency sounds. When angry or defensive, the red panda lets loose with an open-mouthed "huff-quack." During mating, a "twitter" is heard. Cubs make a "wheet" sound when frightened.

Some of the NZP's red pandas are kept in landscaped open yards, like the yard near the Mane Gift Shop. You can often see a group of visitors looking for the red pandas around the pond or in the grass or bamboo. They stand there for a few minutes, then shake their heads in frustration



Born blind, the red panda cub can open its eyes within three weeks. After 70 days, cubs are miniature replicas of adults; after 110 days, cubs are so good at climbing that their mother stops paying them much attention.

and move on—when all they had to do was look *up*, in the trees.

Those who do spot them may wonder why they don't escape. On occasion, they do. . . at least, Bertha Mae does. David Kessler once told me the story of Bertha Mae and the Ice Storm:

A couple of years ago, winter snows and varying temperatures turned the National Zoo into a glassy fairyland. Bertha Mae took full advantage of the situation. There was just enough ice on the metal plate which guarded her enclosure from marauding squirrels to provide trac-

tion for her claws. Within moments, Bertha Mae was up, over, and out.

Miles Roberts went up in a cherry-picker (a truck with a motorized crane in which a person can ride—the telephone company uses them often) to guide Bertha Mae down from a nearby tree. Below them stood a squad of keepers, safety nets at the ready.

But there were more keepers than there were nets, and David was left out. He did, however, have his umbrella with him! When Bertha Mae came down, she spotted another tree and made for it. But David was too

quick for her. He held his mighty bumbershoot against the bark, perpendicular to the tree, and stopped her flight. . . temporarily. Down she came and off she went again. Keeper Oliver Warren, net in hand, lit out after her, slipped on the ice, dropped the net, and wound up with Bertha Mae in his arms and a very surprised expression on his face.

Ah, well. Better, I suppose, the ten-pound Bertha Mae than the 242-pound Ling-Ling. That's one difference between red pandas and giant pandas that Oliver was rather grateful for! □

Will the Rea

Giant Panda

Scientific Name: *Ailuropoda melano-leuca*.

English Translation: Black-and-white cat-footed animal.

Length: Five to six feet long. Tail stubby.

Weight: About 300 pounds.

Range: 5,000 to 10,000 feet above sea level.

Eats: Umbrella and fountain bamboos. In the wild, this diet is supplemented by herbs, flowers, small animals, and occasionally corn and honey. In the Zoo, Hsing-Hsing and Ling-Ling daily eat apples, carrots, cooked rice, powdered cottage cheese, 30-40 pounds of bamboo, soy oil, honey, and various vitamin and mineral supplements. Both animals also eat the grass that grows in their enclosures and drink lots of fresh water.

Young: Usually one; rarely, two or three. This seems to depend on whether the female conceives during her primary springtime heat, or the autumnal heat she may go into if she did not conceive in the spring.

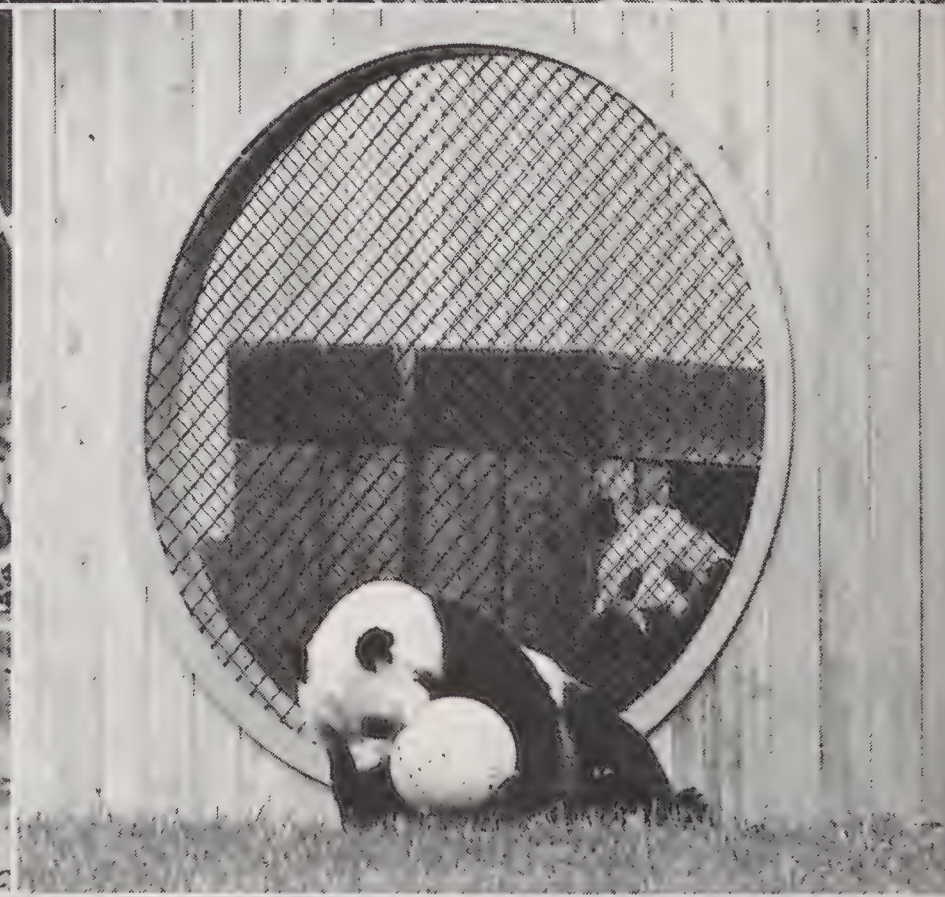
Gestation Period: 118 to 168 days.

Disposition: Solitary, crepuscular, primarily terrestrial. Can climb trees, swim. Friendly as cubs, they become more aggressive as they mature, and will fight fiercely to protect themselves or their territories.

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James Mulvaney



Panda....?



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Red Panda

Scientific Name: *Ailurus fulgens*.

English Translation: Fire-colored or shining cat-bear.

Length: 20 to 26 inches, plus a 12- to 20-inch tail.

Weight: 6.6 to 10 pounds.

Range: 9,000 to 13,000 feet above sea level.

Eats: About a pound of bamboo per day, supplemented by roots, bark, and buds. In the National Zoo the red panda's diet is bamboo supplemented by slices of fruit, and a sweet gruel made of eggs, Gerber baby food, bamboo leaves, honey, applesauce, vitamins, and minerals.

Young: One or two.

Gestation Period: 130 days.

Disposition: Solitary, crepuscular, semi-arboreal. Cubs raised in captivity are easily tamed.

Although the giant panda looks more like bear and the red panda looks more like a raccoon, taxonomists have put them in a family of their own because of the characteristics they share: the flat-footed toes and waddling gait; the reliance on bamboo as principal food; and the pseudo-thumb formation of the wristbone. Other similarities that led to the grouping include teeth and powerful molars, skull structure, tough esophagus and stomach, and short intestinal tract.

In Search of the Fire Cat

BY MILES ROBERTS



The red panda, the giant panda, and the raccoon family all probably originated millions of years ago from one common ancestor—which looked remarkably like today's red panda.

Jan Skrentny

"How are the pandas?" an acquaintance asked.

"Which ones, the little ones or the big ones?" I asked—hoping that, for a change, he meant the little ones.

"Well, the big ones, I guess. You mean you have more than one kind?"

I explained that, yes, there was more than one kind; that the National Zoo has two giant pandas and dozens of red pandas; and that both kinds were doing just fine.

Then, patiently—I've had a lot of practice—I outlined to my friend the differences between the two: where they came from, how they lived, and so on. I was hoping to make a convert of this fellow for the "underdog" red panda.

"Oh," my friend mused. I thought I saw a gleam of understanding in his eye, and felt a wild hope that I'd made a convert. Then he went on, "Will they have babies this year?"

"Who?" I asked expectantly.

"You know, the big ones, the *real* pandas."

I sighed.

This scene has happened so often that I think it's time the story is set straight. And so, dear reader, this is the saga of the "Fire Fox," the resplendently named "Shining Cat-Bear"—the red panda.



Who Came First

Contrary to what my friend thought, the red panda is the “real” panda. It was discovered in 1821, long before Père David stumbled across the large, black and white “bei-shung” in 1869. For 48 years, when you said “panda,” you meant “shining cat-bear.”

It is the original in another way, too: The fossil record shows that creatures remarkably like today’s red panda existed in eastern Europe, Pakistan, southern China, Washington state, and Wyoming millions of years before anything similar to the giant panda appeared.

This tells us that if the giant and red pandas are related—a question still in some doubt—their common ancestor was an animal that closely resembled today’s red panda.

There is no way to authoritatively trace millions of years of evolution, but I interpret the evidence this way: Millions of years ago, there was a group of animals that shared many of the characteristics of today’s red pandas. From this group of animals, the raccoon lineage evolved in the New World in one direction, becoming along the way such species as the coati mundi and the ring-tailed cat. The giant panda lineage went in another direction, but because of rapid specialization evolved into relatively few species, and all but one died out. The red panda lineage evolved in the same direction as the giant panda’s, but not to the same extreme degree, and today’s red panda remains little changed from its remote ancestor. The two species of pandas are now found only in the Orient.

My Elusive Quarry

The red panda is found in steep, forested terrain 7,000 to 13,000 feet above sea level throughout the main range of the Himalayas where human disturbances are minimal. Its largest populations are believed to be in the remote regions of southern China, northern Burma, the tiny kingdom of Bhutan, and Nepal.

In the fall of 1979, supported by a FONZ Conservation and Field Research Grant, I went to Nepal in search of the elusive red panda. My purpose was to study the red panda and its ecological requirements.

I spent several weeks in Tiru Dava, a part of eastern Nepal in the western watershed of the Trisuli River where human encroachment is minimal.

When thinking of Nepal, one visualizes vast mountain ranges—thickly forested, undisturbed, too challenging for human habitation. In fact, a hardy breed of mountain folk have cleared great forest tracts for cultivation, the grazing of domestic stock, firewood, and building material. In some regions only small hilltop patches of forest are left, connected by sparsely forested ridges or isolated like islands. In many cases, even the remaining forests have been irreparably altered through selective cutting and the browsing of goats and cattle.

In Tiru Dava, cultivation is intensive up to 7,000 feet, even though the slopes are achingly steep. From 7,000 to 9,000 feet, the forest becomes thicker and consists primarily of pine. At 9,000 feet one encounters primeval forests of rhododendron and oak and, of course, bamboo. The rhododendrons are huge—some with trunks two feet in diameter that stand

30 feet high and all but block out the light.

Both rhododendrons and oaks are covered with thick mats of lichen and mosses. These may be the key to the puzzle of the red panda's unusual coloration—white face, chestnut body, black belly, ringed tail. The mosses are a deep chestnut color, and they grow on the trees in large clumps and hanging strands that often seem uncannily like the body and tail of a sleeping red panda. The lichens are white and often grow on the lumps of moss, as if to mimic the face of my elusive quarry. Dim and shifting light conspires to complete the illusion. A panda in these trees would be easy to overlook, and I'm sure I did so.

At 10,000 feet, the rhododendrons get smaller. The cloud cover is almost perpetual. Maple trees are replaced by chestnuts, and the forests become taller and more open, with hemlock and fir predominating. Here too, the lichens and mosses cover the trees, giving them an eerie gnarled appearance in the misty air.

Above 10,000 feet, the rhododendrons become smaller still, and the forest community becomes fir, larch, juniper, and cedar. By 13,000 feet, the treeline is marked by the last stunted junipers and the beginning of alpine meadows. It is unlikely that red pandas venture this high except to cross from one valley system to another.

Bamboo, the red panda's staple food, is found in the moist cool forests between 9,000 and 13,000 feet, along permanent bodies of water—in this case, spring- and snow-fed streams. I never saw bamboo grow-

ing farther than about 100 yards from a stream, so I believe the distribution of the red panda is highly dependent on the mountains' network of permanent water courses.

The Inner Panda

Although bamboo is an important food for the red panda, the panda also eats legumes, fruits, wild strawberries, beech nuts, certain leaves, insects, birds, and small mammals.

Red pandas are related to carnivores, but differ from true meat-eaters in that, like the giant pandas, they are specialized for eating large quantities of vegetation. This specialization can best be seen in their molars, which are wide and strong and have many cusps or ridges, well suited to grinding down the tough bamboo leaves and stalks. Carnivores' molars are smaller, for they need only shear the meat from the carcass and give it a perfunctory chew. Most animals that eat both meat and vegetation have molars that are slightly larger than those of the strictly carnivorous—but not as much as the red panda's are.

The red panda has another adaptation for bamboo-eating that is like the giant panda's—an enlarged bone in the wrist. This enlarged bone acts as a pseudthumb to help the panda pick up and grasp its favorite food.

Very little has been learned about the natural habits of the red panda since it was discovered. This is partly because it is found in a remote part of the world, where few naturalists could visit until fairly recently. It is also because the red panda is a small, solitary, nocturnal animal of secretive habits—thus adding to the

difficulty of studying it in the wild. Most of the scanty details of its natural history come from anecdotal accounts by travellers or naturalists who stumbled across lone pandas while seeking other game.

My captive studies at the National Zoo have given clues to some aspects of the red pandas' natural history. For example, red pandas are basically solitary. But on the other hand, a male and a female will live together peacefully year-round—although when the cubs are born males definitely act as if they'd rather be far away! Despite this forced tolerance, attempts to keep more than a pair of adults together have usually resulted in much aggression. At one zoo, females in the same enclosure even kidnapped one another's cubs.

Sexual maturity in red pandas comes at about a year and a half, and they may stay reproductively active for more than ten years—although it is doubtful that they even live this long in the wild. The cubs grow quickly and are weaned at about three months. Our data suggest that they leave their mothers during the breeding season after they're born, as it is then that the mother and the amorous male become somewhat less than tolerant of the cubs.

Red pandas mark their territories by rubbing a mixture of urine and anal scent gland secretions onto trees and rocks with a circular movement of their bottoms. They almost always scent-mark on the ground, although one acrobat was seen scent-marking a branch while hanging underneath it! The animals also advertise their

Donna Grosvenor



NZPO Office of Education



Face like a fox's, tail like a raccoon's, the chestnut-colored red panda shares the giant panda's homeland, but its wider range extends to India, Nepal, Burma, Sikkim, and Bhutan.



James B. Armstrong

The red panda at birth weighs between four and five ounces—the same as the giant panda. But while the red panda grows to an adult weight of five to ten pounds, the adult giant panda is a hefty 300 pounds!

presence by leaving a trail of scent from glands on the soles of their feet. This is a most remarkable device, as far as I know unique among carnivores.

Also unique is the red panda's habit of testing scent trails and novel objects with the underside of the tip of the tongue. In that area are specially modified papillae. The panda touches an object with its tongue, then withdraws the tongue into the mouth briefly; then it repeats

the process again and again. On a number of occasions when we have introduced new animals into an enclosure, the home animal is so busy tongue-testing the scent trails of the new animal that it takes no notice of the "intruder"—even when the intruder is only inches away.

Fighting is rare, but vicious when it happens. Play occurs only between cubs or parents and cubs. Playing animals invite participation by rising up on their hind legs, raising their

forepaws over their heads, and slapping the ground.

Red pandas tolerate the cold very well, but suffer in excessive heat and humidity. But even on the hottest days, their aversion to water keeps them from imitating the giant panda and beating the heat with a nice, long soak. Rather, they stretch out along a branch, exposing as much of themselves as they can to the breezes, and pant like a dog.

The Shining Cat-Bear

The future of the red panda in the wild is uncertain. There are no estimates of numbers, or any more detailed studies than my own of the panda's ecological requirements. It is my guess that in Nepal populations are isolated, small, and diminishing. There are few red pandas in Sikkim and Assam, but I suspect and hope there are still healthy nearby populations in Bhutan, northern Burma, and southern China.

The red panda's well-being in the wild depends wholly on how much human populations intrude on their habitat and on how many animals are killed for their fur or captured for the local and international pet trade.

Whether it is closely related to the giant panda or not, the enigmatic red panda is a zoological oddity in its own right that for years has eluded study and defied attempts at classification.

But I don't expect that the red panda will ever be as popular as its big, black and white cousin is. A low profile is the red panda's style—and why change a good thing after five million years of success?□

ZOO NEWS

A Washington Soap Opera

The organ music swells. The voice of the announcer says:

It has been going on for eight years now. When will the saga end? Is Hsing-Hsing really an inept lover? Has Ling-Ling finally reached her point of total frustration? Will there ever be the pitter-patter of baby panda feet in the National Zoo? What will the future hold for our two black and white celebrities? Are they doomed to be the butts of bad jokes forever?

Over the past three years, everyone on the Zoo staff felt optimistic that Hsing-Hsing and Ling-Ling would produce offspring. We had a lot of excuses for their apparent inability to breed—and we'd heard a lot more rather farther-fetched explanations. Some of these excuses and explanations were: The introduction periods were too long. The introduction periods were too short. They were introduced when they were too young, and they developed bad mating habits out of ignorance. They weren't introduced soon enough. Their diet wasn't right. They were shy. They didn't want to breed in

Doctors Mitchell Bush, Bruce Beehler, and David Wildt attend a slumbering Hsing-Hsing. Although Hsing-Hsing's 1980 contribution to Ling-Ling's insemination proved less potent than that taken in 1979, his "knock-down" did provide much valuable medical data.

front of a crowd. They didn't like each other. Hsing-Hsing was sterile. They were both males. They were both females. And so on.

For what we thought might be the *real* problems, we did what we could. We thought they needed more time—we gave them time. The Chinese suggested that they might be too heavy—we put them both on diets and they both lost weight. Ling-Ling went from a plump 296 pounds to a svelte 242. Their diet wasn't proper?—well, we didn't give them oysters and champagne, but we did provide the optimum vitamins, minerals, and

proteins, plus lots of vitamin E. Were they being given too much time? We shortened the encounter periods.

Nothing seemed to work. Why wouldn't they breed?

Who could have known that the problem wasn't physical, but psychological? From all indications, the difficulty lies with Hsing-Hsing: The body is willing, but the mind is zeroed in on the wrong target. (Ed. note: The article that follows, "A Panda's Good Breeding," discusses this.)

In the years since the pandas came to the Zoo, there have been a number of major developments. There has been a marked change in both animals' behavior patterns. Hsing-Hsing became more aggressive and began to dominate the encounters more and more. And the

Jessie Cohen, NZP Office of Graphics and Exhibits



more domineering Hsing-Hsing became, the more we hoped that Ling-Ling would develop a corresponding submissiveness.

In fact, Ling-Ling *did* seem to be getting more submissive in 1977. In 1977, 1978, and 1979, Hsing-Hsing became very persistent about pursuing Ling-Ling when she seemed to want to end the encounters. Previously, at the first cold shoulder Hsing-Hsing would turn and run away—now he would back off a short distance and then resume his advances.

In addition to Hsing-Hsing's new aggressiveness, in 1978 we observed for the first time two related phenomena: jaw clapping and loud growling. Whether these noises came from frustration on Hsing-Hsing's part or whether they are part of the normal behavior of the mature male panda in rut is debatable—but we believe that they're normal.

In any event, in the period 1977-1979, we knew that the two pandas were both sexually mature, and we felt breeding had to be imminent.

So much for feelings!

On the other hand, we weren't relying on feelings alone. As early as 1978, we suspected that artificial insemination might become necessary. In June 1979, planning ahead, we electroejaculated Hsing-Hsing and froze the semen in liquid nitrogen. Then in spring 1980, after Hsing-Hsing and Ling-Ling again failed to mate, we were ready to try artificial insemination. The article following this one is a detailed discussion of what we did and why.

The artificial insemination was definitely successful in that semen

from the male was injected into the female's uterus at the apparent peak of heat. Also, a great deal of biomedical data was gathered from both animals. While each animal was immobile, blood and skin samples were taken for chromosome counts; secretions from the scent gland areas were taken for our continuing study of scent-marking in animals; blood pressures were checked, plus respiration and heart rates. (Hsing-Hsing's blood pressure was 160 systolic; his heart rate was 180, his respiration 20 breaths per minute, and his temperature 99°. Ling-Ling's blood pressure was 160; her heart rate was 160, her respiration between 35 and 40 breaths per minute, and her temperature 99.2°.) In each case, the immobilization had no side effects, and both pandas resumed their normal activity levels within three days.

While Ling-Ling's behavior gave every indication she was in full estrous, we had no way of knowing whether or not she was ovulating. If the insemination was successful, we won't know for quite a while. And so the saga continues: *Is* Ling-Ling "with panda"? Will she be a good mother? And what about Hsing-Hsing—will he become the first giant panda to be a father by artificial insemination in the western hemisphere?

The organ music swells. The voice of the announcer says:

And what about next year? If nothing happens this year, will we try again?

Stay tuned, folks. The *real* soap opera is about to begin. □

by William A. Xanten, Jr.

A Panda's Good Breeding

As a rule, a couple's sex life is their own business. Moreover, the last time there was passionate public interest in a pregnancy was when Lucille Ball gave birth on national television in 1951. But both rules were broken in 1980 at the National Zoo when Ling-Ling, the darling of Washington's animal lovers, was artificially inseminated in May.

The decision to artificially inseminate was not lightly reached. The procedure called for anesthetizing Hsing-Hsing (Chinese for, roughly, "Twinkle, twinkle, little star") once and Ling-Ling (Chinese for, roughly, "Jingle Bells") twice. Anesthesia for large and exotic animals is still a developing science. Moreover, although the time for the insemination was carefully determined to provide the best possible chances that there would be an egg present and ready to be fertilized, no one can be certain whether the ovum was actually there.

It is believed that female pandas ovulate only once a year, and are fertile for only a 12-hour period (compare this to human females, who ovulate 12 times a year and are fertile for a good two weeks each month).

Artificial insemination of pandas has been attempted five times before by the Chinese, but it has succeeded only twice—and only one cub has survived infancy. There have been a total of 16 giant panda births in captivity—again, all in China—but ten of the infants succumbed to disease soon after birth.

However, captive propagation of

the rare giant panda has become close to urgent recently. The two strains of bamboo that are giant pandas' principal food in the wild, the umbrella and fountain bamboos, blossom and die out every 100 years, leaving only seedlings for three or four years. In 1980 these bamboos are dying out, and the Chinese have to date found more than 150 giant panda carcasses—all dead of starvation.

Ling-Ling and Hsing-Hsing were a gift to the United States from the People's Republic of China. Brought to the Zoo in April 1972, both pandas were born in the wild. Ling-Ling is thought to be about 10½ to 11½ years old, and Hsing-Hsing 9.

Unlike the panda couple given to France by the Chinese, which turned out not to be able to breed since both were male, Ling-Ling and Hsing-Hsing are definitely female and male. But there are still breeding problems.

"For the first five years, it looked like Hsing-Hsing was sexually immature," said Dr. Devra Kleiman, a reproductive biologist who heads the Zoo's Office of Zoological Research. "But in 1977 it became clear that both pandas were sexually mature, and in 1979 it became obvious that they were having problems."

In the wild, the solitary panda mates only once a year. The Chinese believe that—particularly in captivity, where animals live longer and less strenuous lives—the giant panda can breed as late as 20.

Sadly, ignorance has combined with inexperience to ruin the couple's technique. To begin with, Hsing-Hsing is what Dr. John Eisenberg,

Jessie Cohen, NRP Office of Graphics and Exhibits



Despite four tries at mating during 1980, Hsing-Hsing and Ling-Ling couldn't "get it together." Commented Dr. Theodore Reed, Director of the Zoo, "She was willing and he was anxious, but they just couldn't coordinate their efforts."

NZP's Assistant Director for Animal Programs, kindly calls "maladroit." Hsing-Hsing has what it takes, but he doesn't know what to do with it and takes too long trying.

One year when Ling-Ling had a sore paw, she discovered that Hsing-Hsing need not necessarily be fought off when he persevered too long in his attentions: She could discourage him merely by toppling onto her side. Hsing-Hsing, frustrated of his proper outlet, ejaculated on Ling-Ling's back.

By now it appears that, even if Hsing-Hsing could be introduced to an experienced female and taught proper mating techniques, Ling-Ling has learned the wrong responses and

would have to learn not to roll when she tires of a male's attentions.

Dr. Kleiman and Dr. Mitchell Bush, the Zoo's chief veterinarian, regretfully concluded in 1979 that the pandas would need outside help for their 1980 breeding attempt. In June 1979, they began preparations for artificial insemination.

The first step was to bring to Washington Dr. Stephen Seager. Dr. Seager is an associate director of the Institute of Comparative Medicine at Texas A & M University and the Baylor College of Medicine in Houston. A veterinarian, he is one of the very few experts in the electroejaculation, semen storage, and artificial insemination of exotic ani-

imals. He and two colleagues, also reproductive biologists, were brought to Washington with the aid of monies from FONZ's Visiting Lecturer Fund.

In June 1979, Hsing-Hsing was electroejaculated twice over a three-day period. His semen was tested for potency and then frozen immediately by being placed in liquid nitrogen and stored at minus 320 degrees Fahrenheit. Fresh panda semen is believed to stay potent for 12 hours at the most. Hsing-Hsing's frozen semen was checked frequently over the last year for viability, since it was not known how long frozen panda semen might last. (In fact, it did last until May 1980.)

Early in May 1980, Ling-Ling began to go into her once-a-year heat: she began bleating and walking backwards, and her scent-markings—believed to contain hormones that would notify any nearby male of her readiness for action—came more frequently.

On May 15, Hsing-Hsing was allowed into Ling-Ling's enclosure for the first of four fruitless meetings. The encounters, scheduled for dawn and dusk—when giant pandas are most active—were marked by aggressive play, wrestling, boxing, bleating, and nips. Commented Dr. Theodore Reed, Director of the Zoo, "She was willing and he was anxious, but they just couldn't coordinate their efforts." Although Hsing-Hsing tried a number of times, there was no actual breeding.

So at 10:00 a.m., Saturday, May 17, Hsing-Hsing was immobilized and electroejaculated once again. About 3 cc.s of semen was taken. But only 10 percent of the sperm was alive; a

more normal sample would have been 60 to 80 percent. Dr. Bush suspects that the low sperm count was the result of an ejaculation during the couple's unsuccessful



mating try that dawn—since a male panda can apparently ejaculate only once in 24 hours. (This has been the Zoo's experience with Hsing-Hsing.)

Given the less than useful fresh semen obtained, the Zoo decided to use its frozen semen, which was 80 percent alive.

At 3 p.m., once Hsing-Hsing had completely recovered, Ling-Ling was anesthetized and inseminated. Ling-Ling was immobilized and inseminated a second time on Sunday, May 18. A total of 800 to 900 million sperm were injected into Ling-Ling's uterus via a thin metal tube called a cannula. Her posterior was elevated so that gravity might help the sperm travel up to the top of the uterus near the fallopian tubes, where we hope the egg was waiting.

By Monday, both animals seemed completely normal, and Ling-Ling even began showing a decrease in estrous, which may be a hopeful sign.

No one will be sure whether or not

Ling-Ling is pregnant until her 118- to 168-day gestation period is almost up. Urine samples will be taken frequently and checked for any change in hormone levels that might be indicators. Other indicators of pregnancy include a decrease in appetite and, two weeks before birth, a slight swelling of the mammary glands, reddening of the nipples, and loss of hair, plus what Dr. Reed calls "denning behavior"—attempts to build or find a safe and secluded spot to give birth.

Because any certainty of pregnancy will come so close to actual birth, the Zoo plans to proceed just as if it were certain the insemination "took." The Zoo will provide all the construction materials Ling-Ling may need to den, including bamboo, which she may want to have in her nest. A soundproof wall will be put up to protect Ling-Ling's den from noisy visitors. The only observer will be a concealed closed-circuit TV camera to help protect Ling-Ling from any mishap.

Any rejoicing today will be premature. As indicated, the Chinese have tried artificial insemination five times, and succeeded only twice. There is a chance that Ling-Ling was not impregnated. If she was, the embryo may fail to implant. If the baby is born, Ling-Ling's lack of maternal experience or the weakness of the cub's natural defenses against bacteria may result in the worst.

Whatever happens, the Zoo has taken well-thought-out and careful steps to bring about our hoped-for baby panda. If Ling-Ling does give birth, there will be "panda-monium" for sure! □

Panda

continued from page 7.

Little is known of how the giant panda reproduces in the wild. According to early accounts, there is an annual mating season in April. Males were reported to fight among themselves and establish rights to a female by "roaring" persistently while the female watched nearby.

Captive females come into heat in the spring for ten days to three weeks; they also have a briefer and less intense autumn heat. Chinese zoologists say that the fall breeding season occurs in the wild in females that have not become pregnant the previous spring. As for the "roaring," captive pandas of both sexes have been heard making a variety of barking and bleating noises during mating season—but no other noise.

After successful mating and a gestation period of 118 to 168 days, female giant pandas give birth, usually to a single cub that weighs only 4 to 5 ounces—little more than a stick of butter! The mother sometimes carries her infant with her as she travels in search of food, holding it to her breast with one forepaw. Sometimes, too, especially as the infant gets older, she may leave it behind in a hollow tree when she is feeding.

The young panda grows rapidly, increasing its weight 25 to 30 times in the first ten weeks. After ten months, its weight has reached a hefty 60 pounds—about 200 times its weight at birth! Giant pandas have lived more than 20 years in captivity.

Early in 1980, Chinese scientists began discovering dozens of panda

carcasses in the wild. Concern grew as it became clear that the giant pandas were dying because of a quirk of nature. The two species of bamboo that pandas feed on, the umbrella and fountain bamboos, bloom only once, at about 100-year intervals. Only the seeds from the blossoms remain, and it takes several years for the new generation of bamboo to become ripe enough to feed a panda. Chinese scientists estimate that perhaps as much as one fourth of the entire wild population of giant pandas (estimated at 400 to 1,000) has already died of starvation.

Because of the loss of the giant pandas, which the Chinese regard as their national symbol, a joint committee of Chinese and western scien-

tists has been formed to search for ways to help. Dr. George B. Schaller, director of the New York Zoological Society's Center for Field Biology and Conservation, will head the American scientific delegation and set up a long-term research program. Dr. Schaller and his team will be the first westerners since the 1930s to be admitted to Szechuan province to study the giant panda in its natural habitat.

Because of the giant panda's mountainous wild habitat, it has been difficult to find out how the remaining animals are faring or whether the species is in danger. The predicament of the giant panda is a reminder of the precarious state of all wildlife and our dependence on each other for survival. □

CONTRIBUTORS

The Giant Panda:

This article was adapted from a 1975 story, "Panda Lifestyles," by AUSTIN HUGHES, who was editor of *ZooGoer* from 1972 to 1975.

The Lady and the Panda:

MARGERY FACKLAM is a freelance writer based in Clarence Center, New York. She became interested in Su Lin and Ruth Harkness when she was researching her recent book, *Wild Animals, Gentle Women*.

Red Pandas at the National Zoo:

RONN BRACKIN is a Washington-based writer whose interest in animal themes was bolstered by recent volunteer keeper work with red pandas at the National Zoo.

In Search of the Fire Cat:

MILES ROBERTS has been with the National Zoo for ten years. He spent several months in Nepal in 1979 researching the red panda in its natural habitat, supported by a grant from FONZ.

ZooNews—A Washington Soap Opera:

WILLIAM A. XANTEN, JR. started at the Zoo in 1956 as a keeper in the Bird House. His affection for Hsing-Hsing and Ling-Ling began on April 16, 1972, with their arrival at the Zoo, when he was associate curator of mammals.

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BOOK NEWS

A Giant Panda Bibliography

The giant panda—cuddlesome looking if not actually caressable—may be the best-loved and least-known animal in the world. Until a few months ago when George Schaller and a team of American scientists were invited to China, no westerner had been allowed into the panda's remote and forbidding homeland since the 1930s.

As a result, much of the literature on the giant panda is either repetitive, irrelevant, or nonsensical. Even the best of the books available, listed below, contain second-hand material or wide gaps. On the other hand, most are entertainingly written and as comprehensive as their difficult subject will allow. Some of the books below may be out of print and available only through your public library.

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